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No. 898.

HEAVY RAILWAY CONSTRUCTION IN WYOMING.

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Presented March 20th, 1901.

WITH DISCUSSION.

There are many in the East and South who have only faint ideas regarding the heavy construction being generally carried on by the great transcontinental railway lines in their efforts to reduce grades and straighten alignments; and these slight ideas are usually gathered from brief and incomplete notices appearing at irregular intervals in the daily and technical press.

Among others, the Union Pacific Railroad has shown remarkable activity in this direction. Its line has been shortened by many miles, and its grades reduced to a maximum of 0.82 of 1%, compensated 0.03 for each degree of curvature, the maximum curvature allowed being 4 degrees. On all new construction everything is being carried out to a perfect working model.

The highest summit on this line is at Sherman Hill, an elevation of 8 247 ft. above sea level, situated 33 miles west of Cheyenne, and 23 miles east of Laramie, Wyo. This has always been the *bête noir* of the transportation department. To overcome some of its difficulties a

corps of engineers was placed in the field early in 1899 to locate a line from Laramie to Buford, the latter being a small station 7 miles east of Sherman. Several months were spent in locating the line, the final result exhibiting a large amount of curvature and an irregular profile. The summit, however, was lowered 240 ft., and the maximum grade was obtained by tunneling 3 400 ft. Not until the first part of April, 1900, did the company finally decide to construct, and appointed D. C. Dunlap, M. Am. Soc. C. E., as Resident Engineer in charge of the entire cut-off, with headquarters at Laramie. Under the supervision and direction of Mr. J. B. Berry, Chief Engineer, the location at the west end was changed and the cutting at the east end deepened so as to make the length of tunnel 1 800 ft. instead of 3 400 ft.

On April 18th the contract to build the line was awarded to Kilpatrick Bros. & Collins, with a time limit of two years, and a bonus if finished in one year (which meant eight months). This firm afterward sublet the greater part of the work, reserving for itself that portion from Station 978, the west portal of the tunnel, to Station 1 098, these 120 stations being the most difficult part of the entire cut-off.

The writer had immediate charge of what is known as the Second Division, extending from Station 898 to Station 1 109, and his remarks will be confined to operations along these four miles, it being the purpose to present as concise a description as possible of the heaviest part of this very heavy work.

The curvature on this division was comparatively light, the maximum being 3°, with a total of 142° 03′ in angles, divided between four curves; but the grading was extraordinary, the quantities being as shown in Table No. 1.

TABLE No. 1.

Class of Work.	Section No.				Summary.
	18	19	20	21	
Embankment ..... (cu. yds.)	81 545	.....	7 225	723 755	812 525
Earth excavation..... " "	3 860	27 215* / 27 300†	36 391	.....	94 766
Solid granite excavation..... " "	13 214	130 330* / 105 039†	52 569	11 105	312 257
1 800-ft. tunnel, solid granite. " "	.....	35 000	.....	.....	35 000
Totals ..... (cu. yds.)	98 619	324 884	96 185	734 860	1 254 548

* West tunnel approach. † East tunnel approach.

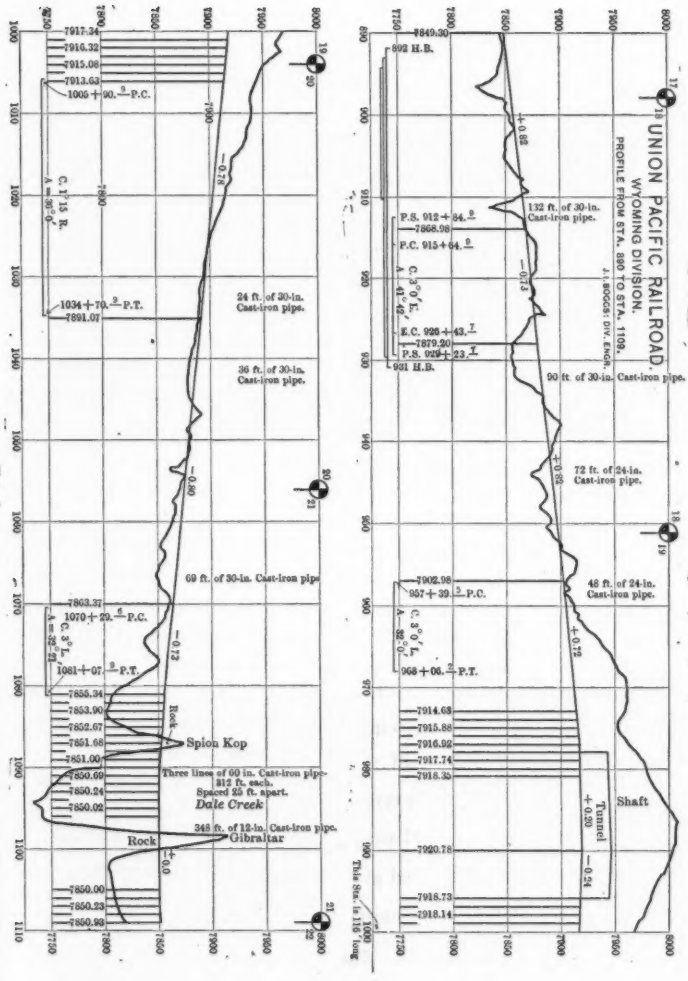
UNION PACIFIC RAILROAD.
WYOMING DIVISION.
PROFILE FROM STA. 890 TO STA. 1102.
J. BOGGS, DIV. ENGR.
7849.30
892 H.B.
+0.68
122 ft. of 30-in. Cast-iron pipe.
P.S. 912+84.9
7868.98
P.C. 915+64.9
C. 5° 0'
D.
A = 41° 49'
E.C. 926+43.7
7879.20
P.S. 929+23.7
931 H.B.
90 ft. of 30-in. Cast-iron pipe.
72 ft. of 24-in. Cast-iron pipe.
7902.98
957+39.5 P.C.
C. 8° 0'
D.
A = 22° 0'
968+06.7 P.T.
48 ft. of 24-in. Cast-iron pipe.
7914.63
7915.88
7916.92
7917.74
7918.35
Tunnel
+0.20
Shaft
7920.78
-0.24
7918.73
7918.14
This sta. is 1100 feet.
7917.34
7916.32
7915.08
7913.63
1005+90.9 P.C.
C. 7° 15'
R.
A = 36° 0'
1034+70.9 P.T.
7891.07
24 ft. of 30-in. Cast-iron pipe.
36 ft. of 30-in. Cast-iron pipe.
-0.74
-0.89
69 ft. of 30-in. Cast-iron pipe.
7863.37
1070+22.6 P.C.
C. 8° 0'
D.
A = 22° 0'
1081+07.9 P.T.
-0.12
7855.34
7853.90
7852.67
7851.68
7851.00
7850.69
7850.24
7850.02
Rock
Spion Kop
Three lines of 60 in. Cast-iron pipe 315 ft. each. Spaced 25 ft. apart.
Dale Creek
348 ft. of 12-in. Cast-iron pipe.
Gibraltar
Rock
+0.0
7850.00
7850.23
7850.93

Fig. 1.

Of the 723 755 cu. yds. of embankment on Section 21, 475 268 cu. yds. were in the fill at Dale Creek, between Stations 1 088 and 1 098. See Fig. 1.

The work was divided as follows:

Station 898 to 907, Mahoney Brothers; Subcontractors.
" 907 to 925, G. C. Smith; "
" 925 to 971, Mahoney Brothers; "
" 971 to 978, Beaumier Contracting Company; Subcontractors.
" 978 to 1 098, Kilpatrick Brothers & Collins; principals.
" 1 098 to 1 100, Rowan & Scott; Subcontractors.
" 1 100 to 1 109, Cushing & O'Keif; Subcontractors.

This being on the summit, there was no bridging to contend with, all water courses being taken care of by means of 24 and 30-in. cast-iron pipe, with the exception of Dale Creek, where three lines of 60-in. cast-iron pipe were laid in concrete. This pipe was in 12-ft. lengths, 2½ ins. thick, and its weight averaged 1 270 lbs. per foot. Of this 60-in. pipe 936 ft. were placed at elevation 7 749, thus impounding 15 ft. of water for a pumping station, Dale Creek being the only constantly flowing stream, of any amount, on the division. The contractors were fortunate, however, in finding innumerable minor springs of very good water all over the country.

Snow storms were of daily occurrence and the ground was covered with snow from 1 to 6 ft. deep on April 21st, when Messrs. Kilpatrick Brothers & Collins began the erection of their camps. One camp was established opposite Station 1 005 and a second on Dale Creek. On April 30th the writer arrived, and found that for two days there had been a violent snow storm. The camps, however, were in good shape and the contractors were ready and anxious to begin work.

At the outset the contractors had to do much preliminary work; the building of a spur track two miles long for the ready delivery of material from the main line of the Union Pacific Railroad; blacksmith and machine shops to be erected; electric light and compressed air plants, with their attendant wire and pipe lines, to be installed; a shaft for the tunnel to be started at once; nearly two miles of double-track 3-ft. gauge railway to be built; a pumping station to be placed on Dale Creek, with a pipe line extending to Station 960; besides many other important items, all demanding immediate and close attention, with not a day's time to lose, as the seasons in this altitude and lati-

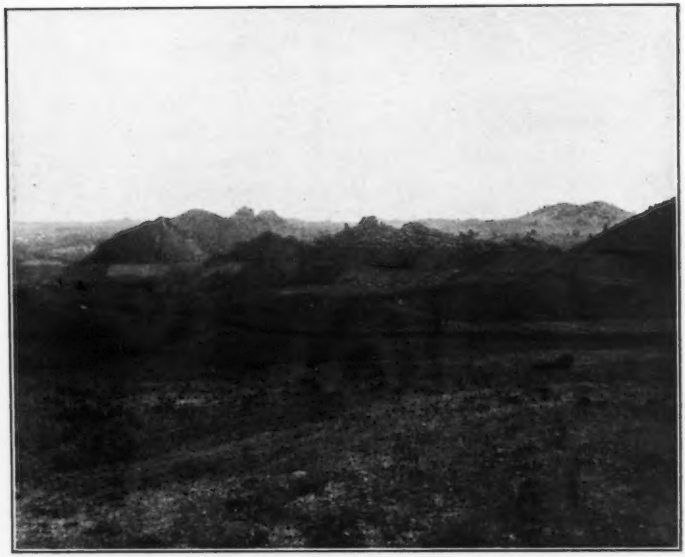

FIG. 1.—GENERAL VIEW OF HEAVIEST PART OF WORK; U. P. RY., IN WYOMING.

FIG. 2.—DALE CREEK FILL, U. P. RY., IN WYOMING.

tude are very short, the last snow storm having occurred on June 9th and the first of the next season on September 26th.

The first efforts at actual construction were directed toward getting a number of teams on the grade between Stations 1 030 and 1 069, and the writer's first duty was to cross-section between these points. On May 1st and 2d, in the midst of heavy squalls of snow, the engineer corps cross-sectioned the rock hill dubbed "Spionkop," between Stations 1 086 and 1 088, fifty rock men being started there at once.

In the morning of May 4th the east tunnel approach was cross-sectioned from Stations 996 to 1 023, and at 1 P. M. of the same day the excavation was commenced.

On the following day cross-sections were run from Stations 971 to 978, being part of the west tunnel approach, and work was started immediately after the stakes were driven, in fact, before all were in. At 5 P. M. of this day the first steam shovel arrived. On May 7th the foundations for the electric light and compressor plants were begun, and five laborers, with a foreman, began sinking a shaft for the tunnel at Station 984. On the same day Mahoney Brothers commenced the erection of their camps opposite Station 955. May 15th may be set as the date of the beginning of actual operations, for, although a number of teams had been working on the grade previous to this date, it was not until this day that the steam shovels were started, one being placed in a borrow pit opposite Station 1 060 and about 350 ft. to the south, a second beginning in the east tunnel approach at Station 1 004. At this time the double-track railway was completed as far as Station 1 070. Fig. 1, Plate I, is a general view of that portion of the work lying between Stations 1 070 and 1 098, "Spionkop" lying a little to the left of the center, with the "Rock of Gibraltar" beyond and to the left, the grade line being shown on the former by the cutting through its peak and on the latter by the working bench, while between the two lies Dale Creek and the famous fill of 475 000 cu. yds.

From this time on, machinery was rapidly put in place, until finally there were in operation eight steam shovels, and fifteen locomotives with trains of from ten to eighteen 3-yd. dump cars each. The machine drills were run by compressed air, and work was carried on both night and day, the works being lighted by electricity.

From May 15th to June 1st steam shovels and teams were engaged in building the embankment, from Stations 1 070 to 1 085, up as high

as the lower level shown in Fig. 1, Plate I, this level striking "Spionkop," near the 7 825-ft. contour, or 27 ft. below grade. On June 4th a line following this contour as closely as possible was located around the hill for the 3-ft. gauge railway, the curves running from 40 to 70 degrees. This is partly shown in Figs. 1 and 2, Plate I. At Stations 2 + 71 and 4 + 73 on this narrow gauge line, split switch points were inserted, and about June 8th the active construction of the immense fill may be said to have been begun, by side-dumping and constantly throwing the track ahead. This side-dumping was continued until about July 19th, when, owing to the failure of the foundries to supply the 60-in. pipe promptly, the work on the west side of the creek had to be temporarily stopped. The contractors then commenced filling to the grade line west of "Spionkop," shown as the upper level in Fig. 1, Plate I. Prior to this, however, a line had been located and constructed on the 7 790 ft. contour, from a borrow pit on the east side of Dale Creek, around the base of "Gibraltar" to the south line of slope stakes. Here, one shovel and two trains were constantly pouring in material, in the quadrant of a circle whose radius was the distance between the opposite slope stakes; the track being occasionally lengthened by means of temporary trestles, one of which may be seen on the left in Fig. 2, Plate I. The location of a part of this line may also be seen in Fig. 1, Plate I. It was not until July 30th that the 60-in. pipes were in place, and work was resumed on the west side. By this time the bank west of Station 1 086 had been filled to grade, as shown in Fig. 1, Plate I, and it became necessary to remove the track from the south side of "Spionkop," disconnecting it at Station 2 + 71 and resorting to filling, in the quadrant of a circle, as was done on the east side. This continued until Station 1 093 was reached, when trestling was used, as shown in Fig. 2, Plate I. The height of the trestling, however, was reduced 20 ft. by having a number of teams build earth bases before its construction was commenced. On August 1st the narrow-gauge track was laid through the rock cut on the top of "Spionkop," and the first bent of temporary trestle for the upper and final lift was erected. Fig. 2, Plate I, shows the condition of the work on September 1st; "Spionkop" being on the extreme right, the first trestle to the left being to grade, the second 30 ft. below, and the one on the extreme left, coming from the shovel on the east side, 60 ft. below grade. December 1st saw this gigantic

PORTAL OF SHERMAN TUNNEL, U. P. RY., WYOMING.

bank of 475 000 cu. yds. completed. This fill is to take the place of a bridge on the main line 127 ft. high. The writer did not agree entirely with the foregoing method of construction, as it was productive of much expense, annoyance and delay. He is of the opinion that had a line been built around "Spionkop" on the 7 790-ft. contour with trestling from the first, it would have been found much more expeditious and less expensive; however, he was overruled in the matter at the time, but since then has had the poor satisfaction of having the contractors tell him that they regretted not having adopted his plan.

As stated, on May 7th, work was begun on a shaft for the tunnel at Station 984, and was continuously prosecuted, night and day, through the solid granite, until on June 13th a depth of 65 ft. was reached, 5 ft. below the springing line of the arch. Here the first difficulties and anxieties of the engineers in charge began, for it now became necessary to set grades and centers for the two headings; one working east, the other west. The writer had no suitable instruments, the best being an ordinary Gurley's plain transit, and a 20-in. level. He also had two 50-ft. metallic tape lines, and two 1-lb. plumb-bobs of cast iron, having points $\frac{1}{8}$-in. in diameter. Placing two 3 x 12-in. planks securely over the shaft, two nails were set on center and partially driven. A wire, fastened at each end to the nails, was then stretched across, and the two plumb-bobs were suspended therefrom. Two holes, one on each side, were then drilled 1 ft. above the crown, two wooden plugs were inserted, the plumbs were again dropped and two nails set. For elevation, two metallic tape lines were tied together and the elevation was measured in from a bench set at the edge of the shaft and checked by means of a wire measured to exact length over the level rod. Hoisting engines, gallows frame, and blacksmith shops were soon erected, and in a short time the center line was completely obstructed, so that when the headings were driven about 75 ft. on each side, and centers had to be reset, the first having been blown out, it became necessary to use an offset line. This, the writer disliked doing, owing to the poor character of the instruments at hand; however, it was imperative and he had no choice in the matter. At Station 992, east of the shaft, a right angle was turned and an offset line 60 ft. to the south established, and carefully checked in on a point at Station 982, to see that it was parallel. A point was then established opposite the shaft and a line run

across it at right angles to the direction of the headings. Two nails were again set, a wire stretched between and the two plumb-bobs dropped 9 ft. apart. A distance of 55½ ft. was carefully measured to the first and a point set beneath it in the floor of the shaft; the second was allowed to remain suspended as a foresight. Right angles were then turned and an offset line 4½ ft. south of the center was run along the floor of the headings in both directions. For the center, points in the roof were then set from this line, and plumbs suspended from them. For a check, as 3 ft. to the north would clear the obstructions east of the shaft, an offset line at that distance was run across it, and the two plumbs suspended with 6 ft. between them, a point being taken below one; the other remaining suspended, as before, for a sight. A 3-ft. offset line was run along the floor of both headings, and the points in the roof, previously set, were checked from this. These points checked fairly well, and were thereafter used to prolong the line when necessary.

The operations noted, while simple enough above ground, are very different beneath it, in a small comparatively dark hole, working by candle light, with the clatter of machine drills on all sides, gangs of "muckers" waiting, etc., especially when only very common field instruments are available. Unless the engineer in charge has a cool, clear-headed instrumentman he is likely to experience considerable trouble where the headings meet.

On one occasion, the instrumentman declared that nothing more could be done, as the cross-hairs had slackened so badly, from the surrounding moisture, that he could not set a point within ¼ in. Something more had to be done, as it was imperatively necessary to set a center ahead; so, in desperation, the writer picked up a couple of candles and placed the flame under the diaphragm of the cross-wires. This dried and straightened them up, and, with occasional applications of the candle flame, the work proceeded.

On July 6th the heading east from the west portal at Station 978, was started, and on August 23d, at Station 981 + 37, it met the heading being driven west from the shaft. The center line was then carefully checked up and was found to be exactly correct at Station 984, at the bottom of the shaft; while, where the two headings met, it was found that the line from the shaft was precisely 1 in. too far north, showing that a slight angle had been obtained in dropping the plumbs.

FIG. 1.—EAST APPROACH TO SHERMAN TUNNEL, LOOKING EAST.

FIG. 2.—EAST APPROACH TO SHERMAN TUNNEL, LOOKING WEST.

On July 26th the heading west from the east portal was started and continuously driven night and day until on December 8th, at Station 988 + 37, it met the heading driven east from the shaft. Work on the latter heading had been stopped on September 26th, after being driven 437 ft. At that time the force was put on the bench. The entire time occupied in driving the headings is shown in Table No. 2.

TABLE No. 2.

	Days.	Number of feet driven.	Average rate, in feet, per day.
West Portal	49	337	6.88
West Shaft	72	263	3.65
East Shaft	106	437	4.12
East Portal	139	763	5.49
Totals and average	366	1 800	4.92

Usually, six drills on three columns were worked in the headings, the cut being drilled 8 ft. and the round 10 ft. The most difficult and treacherous rock encountered was between the shaft and the west portal, and all this part will have to be timbered; while from the shaft to the east portal the material was very firm. The bench was taken out in two lifts, and the progress has been as shown in Table No. 3.

TABLE No. 3.

	Days.	Feet.	Average rate, in feet, per day.
West Portal	92	373	4.06
West Shaft	91	227	2.49
East Shaft	97	453	4.67
East Portal	51	180	3.53
Totals and average	331	1 233	3.73

Much time was lost between the completion of the heading and the starting of the bench at the west portal, as the entire heading had to be slowly and carefully timbered. As shown by the foregoing figures, 567 ft. of bench yet remain to be taken out, between the shaft and the east portal; this, at the present rate of progress, will require about 70 days' more time. It is hoped, however, that this estimate will be materially reduced.

The forces employed in driving this tunnel, so far, reduced to a unit of one day, together with the wages paid, are shown in Table No. 4.

TABLE No. 4.

	Force, reduced to a unit of one day.	Wages paid.
Drillers	7 230	$3.25 per day
Drill helpers	8 710	2.25 "
Muckers	19 980	2.25 "
Foremen	1 236	125.00 per month
Total of all classes	37 156	

No water, of any amount, has been encountered. Plate II illustrates the method used in hoisting muck at the west end; it being then run out to the waste bank by cars. The frame-work on the right is the dumping frame for the skips. At the shaft the muck was hoisted in cages, in 1-yd. steel cars, which were run out on the waste bank and dumped. At the east portal, track was laid in as the work progressed, and the muck was run out through the east approach, and wasted.

Fig. 1, Plate III, is a view of the east approach, showing the condition of the work on July 23d. Fig. 2, Plate III, is another view of the same on August 25th. The tunnel heading can be seen near the center; on the right are the machine and blacksmith shops, the electric light and compressed air plant, known as "The Power House," while over the hill, and above the excavation, is the top of the smoke-stack of the hoisting engine and gallows frame at the shaft.

On May 22d Roman & Scott, with a force of eleven men, about all that could be worked to advantage, began excavating the deep rock cut at the hill dubbed "Gibraltar." This was a peak of solid granite, 70 ft. above the grade line at the highest point. Operations commenced by running a 3 × 4 ft. tunnel along the center line and at grade for 50 ft. An ell, 20 ft. long, was then drifted to the north, and charged with 8 750 lbs. of powder. Fig. 1, Plate IV is a view of the original hill with the tunnel entrance a little to the right of the center. This excavation was completed on November 1st.

On May 24th Cushing & O'Keif began on their 110 000-yd. embankment, 900 ft. long, and finished it on October 20th.

FIG. 1.—"GIBRALTAR," U. P. RY., IN WYOMING.

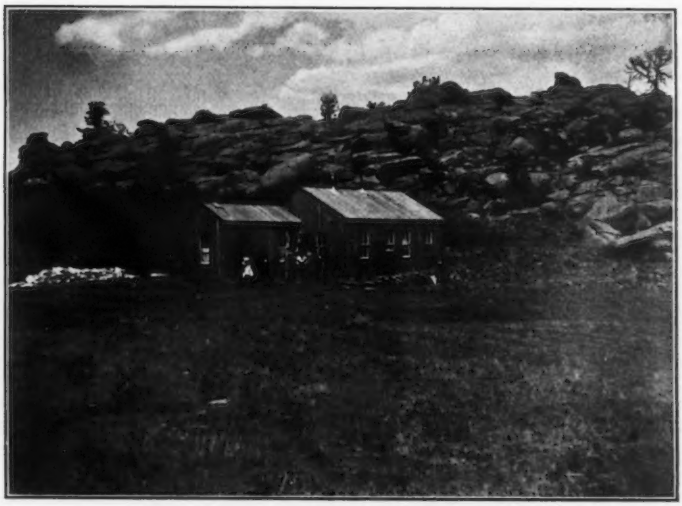

FIG. 2.—ENGINEER'S HOUSE, U. P. RY., IN WYOMING.

On June 16th the Beaumier Contracting Co. started on their 60 000-yd. excavation, 86% of which was solid rock, and finished it on December 31st.

On May 10th Mahoney Bros. started on their sub-contract, and will probably finish in February, 1901. Nearly all their excavations have been through the very hardest granite, and considerable difficulty has been encountered in moving it, on account of the immense amount of drilling necessary before the steam shovels could properly handle it. All the shallow excavations between Stations 907 and 925 consist of hard granite, and the roadbed being 47 ft. wide, on account of side tracks, made it very difficult; however, it was well handled. On July 31st Mr. Smith began by drilling holes 4½ and 5 ft. apart all over the surface, and on October 15th had finished the entire eighteen stations.

Out of 1 250 000 cu. yds. to be moved on the 4 miles, only 12 000 cu. yds., exclusive of the tunnel, remained on December 31st, 1900.

The specifications admitted of but two classifications, "Earth" and "Rock." All that could not be ploughed with a No. 1 breaking plow and six horses had to be classed as solid rock. To draw the line between the two was sometimes very difficult.

The writer does not claim anything extraordinary about this work, except the wonderfully short time in which an immense amount of railway grading can be accomplished with modern appliances and methods under difficult and discouraging conditions. One of the greatest annoyances to which the contractor is subjected in this section is the worthless, thriftless class of men he has to depend upon for labor.

Sections 18, 20 and 21 were entirely finished on December 31st, 1900, and final estimates were rendered. On Section 19 Mahoney Bros. still have about 12 000 cu. yds. to move and some sloping to do. Beaumier has to do some slope trimming, and not quite one-third of the bench in the tunnel has yet to be moved, while in the east approach about one-half the slopes have to be trimmed up and the cut ditched —the latter being difficult, owing to the frozen condition of the ground.

A profile of this division is shown in Fig. 1. From the start to the present time the forces, reduced to a unit of one day, have been as shown in Table No. 5.

TABLE No. 5.

Contractor.	G. C. Smith.	Mahoney Bros.	Beaumier Contracting Co.	Kilpatrick Bros. & Collins, and Wood Bros.	Roman & Scott.	Cushing & O'Keif.
Men.						
Foremen	230	1 046	704	6 854	203	240
Laborers	2 115	13 710	10 354	50 922	1 117	1 957
Drillers	385	1 850	527	7 625	307	.....
Machinemen	116	1 712	1 364	19 243	.....	.....
Trainmen	.....	1 488	.....	7 263	.....	.....
Totals	2 846	19 806	12 949	91 907	1 627	2 197
Teams.						
Scrapers	920	1 016	452	4 854	9	2 952
Carts	134	.....	.....	.....	216	.....
Plows	144	235	77	610	....	295
Wagons	.....	305	.....	520	.....	.....
Cars	.....	24	839	1 521	.....	107
Totals	1 198	1 580	1 368	7 505	225	3 354

G. C. Smith's Plant.

1 12-H.-P. portable boiler.

2 machine drills and a number of hand drills.

Mahoney Brothers' Plant.

1 55-ton Vulcan steam shovel; 60 H.-P., geared up to 100 H.-P.; capacity of dipper, 2 cu. yds.

1 80-ton Vulcan steam shovel; engines, 13 x 15-in.; single engine, 46 H.-P.; double engine, 96 H.-P.; geared up on gear and pinion four times and on hoisting chain twice; capacity of dipper, 3½ cu. yds.; boiler, 100 H.-P.

1 Barnhart, model "A," shovel. (The work done by this shovel was insignificant.)

1 10-ton locomotive; cylinders, 8 x 14 ins.

1 12-ton " " 9 x 14 ins.

50 3-yd. Western dump cars.

2 12-H.-P. stationary boilers.

1 10-H.-P. portable boiler.

6 machine drills.

1 complete derrick.

There were 267 steam-shovel days, and 384 locomotive days, with

3 421 cars in service. No record of the average car output was kept. The average length of haul was about 2 700 ft.

Beaumier Contracting Co.'s Plant.

1 45-ton Barnhart, model "A," steam shovel, of 50 H.-P., geared up to 75 H.-P.; capacity of dipper, 1½ cu. yds.
50 1-yd. dump cars, hauled by teams.
2 machine drills.
1 complete derrick, with 12-H.-P. stationary engine.
Shovels, picks, etc.

There were 131 steam-shovel days, with 3 206 cars in service. The average haul was 1 400 ft.

Plant of Cushing & O'Keif.

1 377 1-yd. cars.

Plant of Kilpatrick Brothers & Collins, and of Wood Brothers.

Machinery in Shops.

3 100-H.P. boilers.
1 air compressor, 250 H.-P.
1 " " 200 H.-P.
2 receivers (air usually carried at 6 atmospheres).
3 blacksmiths' forges.
1 steam hammer, 100 lbs., 2-ft. drop.
1 Am. Tool Co. lathe, 36-in. swing, 8-ft. centers.
1 " " " 24-in. " 16-ft. "
1 planer, 14-ft. bed, 3 ft. under head.
2 drill presses, 5½ ft. and 3 ft.
1 bolt cutter, ½ in. to 1½ in.
1 Rice's automatic engine, 9 x 15 ins.
1 30-H.-P. high-speed engine.
1 30-H.-P. Atlas engine.
1 72-H.-P. dynamo, 250 volts.
1 50-H.-P. dynamo, 125 volts.
1 40-H.-P. boiler.

Machinery at Shaft.

1 Lidgerwood double hoisting engine, cylinders 10 x 16 ins., with double drum.
1 75-H.-P. boiler.
2 steel shaft cages, 7 500 lbs. each.
8 1-yd. steel cars.
1 blacksmith's forge.

Machinery at West Portal.

1 pair of hoisting engines, 7 x 9 ins.
1 40-H.-P. boiler.
1 blacksmith's forge.
1 complete derrick.

Steam Shovels.

1 90-ton Barnhart, Model "K"; boiler, 100 H.-P.; engines, 13 x 15 ins.; single 46 H.-P.; double, 92 H.-P.; geared up on gear and pinion four times and on hoisting chain twice; capacity of dipper, 3½ cu. yds.
1 60-ton Barnhart, Model "G"; boiler, 75 H.-P.; engines, 12 x 14 ins.; single, 30 H.-P.; double, 60 H.-P.; geared up on gear and pinion four times and on hoisting chain twice; capacity of dipper, 2½ cu. yds.
1 70-ton Bucyrus, No. 350; boiler, 75 H.-P.; engines, 10 x 16 ins. single, 35 H.-P.; double, 70 H.-P.; geared up on gear and pinion five times and on hoisting chain twice; capacity of dipper, 2½ cu. yds.
1 50-ton Bucyrus, No. 157; boiler, 70 H.-P.; engines, 10 x 14 ins.; single, 30 H.-P.; double, 60 H.-P.; geared up on gear and pinion five times and on hoisting chain twice; capacity of dipper, 2½ cu. yds.

On the Works, Generally.

7 12-ton Porter engines; cylinders, 9 x 14 ins.
1 10- " " " 8 x 11 "
1 10- " Porter & Bell engine; cylinders, 10 x 12 ins.
2 15- " Baldwin engines; cylinders, 10 x 16ins., 6-wheel connected.
1 15- " " " 10 x 15 " " "

4 Fairbank's M. & Co. pumps, 6 x 4 x 6 ins.
250 3-yd Western dump cars.
50 1-yd. dump cars.
25 machine drills.
3 water tanks; 8 000 galls. each.
5 wagon tanks.
2½ miles of 3-in. iron pipe.
3 600 ft. of 4-in. iron pipe.
2 000 " 2½-in. "
300 " 1½-in. "
1 000 " 1-in. "

Also a number of shovels, picks, lanterns, cables, etc., etc.

The actual shovel output is shown in Table No. 6, together with the average haul, etc.

TABLE No. 6.

Shovel.	Cars.	Average haul.
Bucyrus, No. 157	14 094	2 000 ft.
Bucyrus, No. 350	61 436	8 000 "
Barnhart, Model "K"	65 791	9 500 "
Barnhart, Model "G"	58 221	1 600 "
Total	199 542	.....

There were 472 steam-shovel days and 1 479 locomotive days, with 17 898 cars in service.

The quantity of powder used by Kilpatrick Brothers & Collins on their portion of the work, between Stations 978 and 1 098, was as follows:

Gelatine	106 700 lbs.
Dynamite (50%)	49 350 "
Judson powder	10 600 "
Black powder	139 250 "
Total	305 900 "

For skilled labor the rate was generally $3 per day; for unskilled labor $2 per day, and for foremen $100 per month.

There have been few accidents, considering the magnitude of the

work. Three men have lost their lives, and less than a dozen have been injured, only two of these seriously.

Too much praise cannot be given to the contractors, Messrs. Kilpatrick Brothers & Collins, and Wood Brothers, for the vigorous manner in which they carried out the work.

Fig. 2, Plate IV, exhibits the style of houses built by the Union Pacific Railroad Company for the use of the Division Engineers and their parties. On the right of the main building is a large room, accommodating eight men with comfort; in the center is the living room and kitchen; on the left is the engineer's office and bedroom. The ell consists of two rooms for the accommodation of the engineer's family. The house was double-walled, with tar paper between, and closely ceiled.

No trouble or expense was spared by Mr. Dunlap in making the men under him comfortable; the house was well and completely furnished by the company, and there was a plentiful fuel supply, which is greatly needed in that severe climate. The house was lighted by electricity from the "Power House."

The writer desires to return thanks to his instrumentman, Mr. A. J. Wharf, for his careful, patient and painstaking work, which made it possible to accomplish such good results.

It may seem that this paper is premature, because the work is not yet finished. The writer regrets this, and offers in excuse the fact that the present seemed to be the only time which he could devote to its preparation.

DISCUSSION.

EMILE LOW, M. Am. Soc. C. E. (by letter).—The writer desires to draw attention to some heavy railway construction in Virginia, on the line of the Clinch Valley Division of the Norfolk and Western Railroad (now Railway). This division extends from Graham, on the Norfolk-Columbus Division, to Norton, the junction with the Louisville and Nashville Railroad, a distance of 100 miles. The line traverses the mountain region of Southwestern Virginia, forming the western slope of the Allegheny Mountains. Some of the mountain peaks in this section reach an altitude of nearly 5 000 ft. above sea level. The line generally follows Wright's Creek (a tributary of the New River), Clinch River, Thompson's Creek and Guest's River, the two latter being tributaries of Clinch River. Very heavy work occurs at the divides where the line passes from one valley to another; especially is this the case between St. Paul and Colburn. The cost of the heaviest sections, usually one mile in length, in round numbers, was as follows: Section 57, $100 000; Section 81, $121 000; Section 85, $166 000; Section 86, $114 000; and Section 89, $153 000. Six tunnels, ranging in length from 327 to 1 925 ft., occur on the sections mentioned, hence the large cost. Mr. Low.

On the hundred miles there were 25 sections the cost of which ranged from $40 000 to $166 000, with a total cost of $1 718 000, or an average of nearly $70 000 per mile, the cost of the track not being included.

It is the writer's intention, however, to mention more specifically the construction of Sections 31 to 35, inclusive, between Pounding Mill and Cedar Bluff, where the construction consisted almost wholly of open excavation and bridging. On these sections there are only three short tunnels, 155, 437 and 540.5 ft. long, respectively. The railway between the points mentioned follows the valley of the Clinch River, a tortuous mountain stream, which cuts its way through a range of limestone hills, known locally as Kent's Ridge. The river is crossed ten times. Near Pounding Mill five crossings occur within half a mile; the other five crossings occurring within the last 6 000 ft., near Cedar Bluff.

The course of the Clinch River east of Pounding Mill is comparatively straight, but the south bank is an almost perpendicular cliff for the distance mentioned. The course of the river just west of Pounding Mill is very sinuous, the distance between Bridges 1338 and 1342 (known as Crossings 9 and 13, of Clinch River), measured along the center line of the railway is 2 700 ft., while the length of the stream between the same points is about 7 600 ft., or nearly three times as long.

As previously stated, the river is crossed five times in about half a

Mr. Low. mile. The crossings range from 33 to 44 ft. in height, between base of rail and water surface. The bridges are Howe trusses, resting upon masonry substructures. For the higher bridges, trestles are used for the approaches on either side of the main span.

There being practically no embankment on this 2 700-ft. section, nearly all the material from the excavations had to be wasted. The narrow ridge between Bridges 1340 and 1341 is pierced by a short tunnel known as Tunnel No. 1.

Some of the bridges near Cedar Bluff are located on curves, the others on tangents, and T-walls were here substituted for the short spans at the ends.

The strata in the section mentioned dip to the south, the dip ranging from 30 to 45 degrees. This fact largely increased the quantities of excavation, as the cuts, upon being excavated, assumed slopes on one side corresponding to the dip of the rock, the excess material beyond the prescribed slope lines being literally solid rock slides—an uncommon kind of slide.

In one case a slide of this character occurred after the track was laid. This was in the cut between Bridges 1338 and 1339. One night, during a heavy rain, the upper side of the cut slid in, covering the track to a depth of over 20 ft., for a length of about 400 ft., about 90% of the slide being composed of solid rock.

The heaviest work occurred on Section 31, where the south bank formed an almost perpendicular wall over 110 ft. in height, from the surface of the river up.

Section 33, comprising what was called the Horse Shoe Bend, was the lightest.

Tunnels Nos. 2 and 3 were located on 8° curves. As the tunnels were worked from both ends it was very essential that the alignment should be correct. Previous to construction the center line was carefully re-run, all measurements being made with steel tapes. At convenient places outside of the tunnel portals, points on the center line were established, and lines tangent to the curve run out to intersections. The tangents were carefully measured, as also the long chords and versed sines. After all measurements were found to agree with the theoretical calculations, the line was carefully referenced and construction started. It is quite needless to say that the work from each end met, absolutely.

The price paid for tunnel excavation, proper, was for the material only between the neat lines of the prescribed cross-section. On account of the inclination of the strata passed through, there were more or less falls, or breakage, as it was termed. The contractors were paid for this excess material, beyond the prescribed section, at a reduced price. The percentages of this breakage, as compared with the neat or prescribed sections, for the different tunnels were as follows:

No. 1, 19%; No. 2, 16%; No. 3, 24 per cent. These percentages of falls may seem large, but were wholly attributable to the inclination of the strata, as before mentioned. Mr. Low.

Hand-drilling was largely used in excavating these tunnels, although steam drills were used occasionally.

The tunnels required no timbering, except that a short length of timber lining was put in at the west portal of Tunnel No. 2, where the material was subject to disintegration.

There was no contract price for foundation, coffer-dams and other items connected with bridge foundations. This and other work was termed "extra work" and was paid for by force account, the contractor being paid the actual cost of labor and materials, plus 15% for use of tools and superintendence.

Each day the contractor furnished the resident engineer with an itemized statement of all the extra work done on the previous day. This statement was made out on blank forms supplied by the railway company, and showed in detail the kind of extra work performed, the locality, the number of workmen of all classes engaged, quantities of material used, rates of pay and of material, and the money amount for the day. A separate report was made for each piece of work. These daily reports were duly checked by the resident engineer, and all discrepancies, if any, harmonized and corrected at once.

A weekly summary of all extra work performed was sent to the division engineer for inspection and approval, and also for information, so as to enable him to modify or change any particular piece of work, if the expense seemed unreasonable.

Monthly bills were prepared from the daily reports, each piece of work being duly itemized and charged to the section to which it belonged; this method being preferred to the somewhat usual practice of converting the amounts into quantities of excavation and thus being lost to view in the general result. Table No. 7 gives in detail the quantities and cost of the work.

TABLE No. 7.

Section No.	Open Excavation.				Tunnel Excavation.		Masonry, all classes.	Clearing and grubbing.	Cost, including bridges.
	Earth.	Loose rock.	Solid rock.	Total.	Regular.	Breakage.			
	Cu.yds.	Cu.yds.	Cu. yds.	Cu. yds.	Cu.yds.	Cu.yds.	Cu.yds.	Acres.	
31.....	6 347	4 922	85 623	96 892	.....	.....	928	7.09	$76 000
32.....	10 599	8 477	63 022	82 098	1 514	288	1 019	9.61	82 000
33.....	1 100	7 271	27 029	35 400	.....	.....	146	12.19	24 000
34.....	4 924	4 619	31 171	40 714	5 252	821	1 520	5.69	66 000
35.....	6 651	2 560	26 528	35 739	6 126	1 467	1 742	4.47	70 000
Totals..	29 621	27 849	233 373	290 843	12 892	2 576	5 355	39.05	$318 000

Mr. Low. The cost of Section No. 36 was $54 000.

The cost of track is not included in Table No. 7.

It will be noticed that a large percentage of the material excavated was solid rock, the earth and loose rock being merely thin coverings overlying the solid rock.

The various percentages of the excavation were: Earth, 10.2; loose rock, 9.6; and solid rock 80.2.

The following are the contract prices paid for the various items of work:

Earth excavation	$0.18	per cubic yard.
Loose rock excavation	0.35	" "
Solid " "	0.75	" "
Tunnel excavation	3.25	" "
Tunnel breakage	1.50	" "
Rock-face ashlar masonry	8.00	" "
Broken range "	6.00	" "
Box culvert "	3.00	" "
Dry paving "	1.50	" "
Rip-rap "	1.00	" "
Clearing and grubbing	30.00	per acre.

These prices were fixed by the chief engineer, and were the prevailing prices for the whole line.

The cost of the explosives for the open excavation was approximately 5, 10 and 15 cents for earth, loose rock and solid rock, respectively.

The wages paid were $1.20 per day for laborers, who were nearly all negroes, and $3 per day for foremen.